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(54) Telecommunications access system and equipment

(57) A higher data rate signal such as ATM (Asynchronous Transfer Mode) fixed size data packets and lower data rate signals such as ISDN are transmitted along the same link by accommodating the ISDN in unused time slots in the overall frame structure. The cells also contain a field containing incremented numbers of modulo-n and, in the reverse direction along the link, frames are transmitted which acknowledge receipt of those sequence numbers. If the next expected number is not received, the sequence transmitted is restarted at that number.

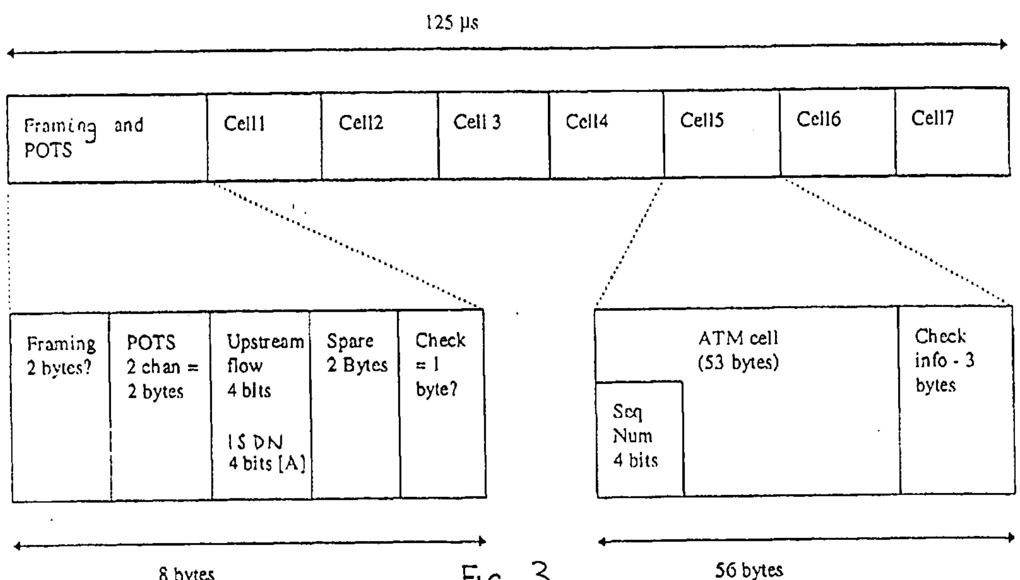

FIG 3

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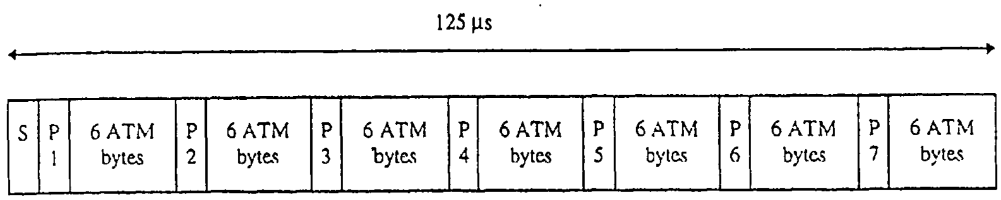
125 µs
S
P 1
6 ATM bytes
P 2
6 ATM bytes
P 3
6 ATM bytes
P 4
6 ATM bytes
P 5
6 ATM bytes
P 6
6 ATM bytes
P 7
6 ATM bytes

FIG 4

Description

This invention relates to telecommunications access systems and equipment.

Systems for carrying data at increased rates are being developed, and offer the chance to extend the range of services which customers can access using the terminal in their homes. Thus, while existing terminals can handle services according to the ISDN specification such as facsimile transmission or computer communication in addition to speech, higher data rates would offer the chance to transmit television signals into the user terminal as well as to permit interactive viewing.

A problem arises as to how to combine the higher data rate services such as ATM (Asynchronous Transfer Mode) with the existing lower data rate services such as ISDN services. In ATM, information is contained in fixed sized data packets known as cells, typically 53 byte long, which are long enough for data but short enough for delay sensitive devices (ITU Recommendations I-150).

Among the access methods being developed for high speed data transfer for terminal users are VDSL (Very High Speed Digital Asymmetrical Subscriber Line), HDSL (High Speed Digital Subscriber Line) and ADSL (Asymmetric Digital Subscriber Line). ADSL is described in ANSI Reference T1.413.

Typically, VDSL could operate with a data rate of up to 25Mbit/sec in one direction and 3Mbit/sec in the other direction. Typically, HDSL has data rates up to 2Mbit/sec in each direction and ADSL has rates up to 6Mbit/sec in one direction, and a few 100kbit/sec in the other direction. Compared to this, basic rate ISDN is generated typically at 144kbit/sec.

The Applicants considered combining the ATM and the ISDN elements in several ways.

Referring to Figure 1, the bandwidth occupied by analogue telephony is as indicated by "AT" and the bandwidth for ISDN is indicated "ISDN". The Applicants considered transmitting the VSDL signal at higher frequencies than the ISDN ie. not as shown in Figure 1. The problem with this is that ISDN uses up spectrum fairly inefficiently compared to VDSL using Discrete Multi-Tone Modulation (DMT) or Carrierless Amplitude and Phase (CAP) and, if the VDSL signal were to be carried at higher frequencies, inherent restrictions as to the highest frequency which can be carried by a communication link (in particular a copper wire pair) require that the bandwidth available for VSDL would have to be restricted from the bandwidth shown in Figure 1, reducing the capability of carrying VDSL from 25 to perhaps 12Mbit/sec.

The Applicants also considered dedicating one or more of the number of discrete carriers generated by digital multiplexed equipment (normally used to deliver one large channel) specifically for carrying the ISDN, leaving the rest to carry the ATM. However, the two elements are very separate, and an evolution later whereby both ISDN and ATM material would come from the same source eg link 4, would become relatively complex.

The Applicants also contemplated arranging the ISDN data in the form of the same data packets as ATM uses and then transmitting the information in this way. However, the latency of the packetisation is high which would mean that the ISDN link would no longer conform to requirements.

This invention provides a method of delivering a higher data rate signal representing first services and a lower data rate signal representing second services along the same link, comprising the steps of receiving the separate signals from a communications network, and transmitting along the link the higher data rate signal in fixed size data packets within frames, the lower data rate signals being accommodated in time slots in the frames not occupied by the fixed size data packets.

The invention also provides a multiplexer for delivering a higher data rate signal representing first services and a lower data rate signal representing second services along the same link, comprising ports for reception from a communication network of the separate signals, and means for transmitting along the link the higher data rate signal in fixed size data packets within frames, the lower data rate signal being accommodated in time slots in the frames not occupied by the fixed size data packets.

The invention also provides network terminating equipment for receiving a higher data rate signal representing first services and a lower data rate signal representing second services along the same link from a multiplexer, comprising means for receiving from the link the higher data rate signals in fixed size data packets within frames, the lower data rate signal being accommodated in time slots in the frames not occupied by the fixed size data packets, and means for extracting the first services and the second services.

The invention avoids the disadvantages noted above. The lower data rate signal eg. ISDN, does not suffer from much delay, and it is possible for the system to be designed so that it can migrate later when the lower data rate signal eg. ISDN and the higher data rate signal eg. ATM come from the same source.

The time slots which accommodate the lower data rate signal may be part of a data packet containing a synchronisation pattern ie. a framing data packet.

Advantageously the data packets transmitted across the link include a field containing a number which changes from packet to packet in a regularly repeating sequence, the receipt of the packet number in the sequence being acknowledged. The system may be such that, in the event that the next packet in the sequence is not received across

the link, the sequence being transmitted is restarted at that next packet.

Telecommunications access systems and equipment, including a multiplexer and network terminating equipment, constructed in accordance with the invention, will now be described, by way of example, with reference to the accompanying drawings in which:

Figure 1 is a schematic diagram to show the regions of the frequency spectrum occupied by various signals down the link;
Figure 2 shows the connection of the multiplexer and the network terminating equipment in normal operating conditions;
Figure 3 illustrates a frame sent out by the multiplexer to the network terminating equipment;
Figure 4 illustrates a frame sent out by the network terminating equipment to the multiplexer;
Figure 5 illustrates a frame at an alternative data rate sent from the multiplexer to the network terminating equipment; and
Figure 6 shows a frame at an alternative data rate sent from the network terminating equipment to the multiplexer.

Referring to Figure 2 a simple copper wire pair 1 links a multiplexer 2 in a street cabinet with network terminating equipment 3 in a home. In turn the multiplexer 2 in the street cabinet is linked to a local exchange or to a concentrator firstly by means of an optical fibre connection 4 and secondly by means of a copper wire pair 5.

The optical fibre 4 carries ATM (Asynchronous Transfer Mode). Typically, the ATM data is be clocked at 155Mbit/sec upwards. The copper wire pair 5 carries ISDN which is typically clocked at 144kbit/sec. It follows that both links 4 and 5 can be relatively long, say, up to 9 km.

At the multiplexer 2, the incoming ATM data and ISDN data are multiplexed together and transmitted along the copper wire pair link 1 into the home in VDSL format using DMT. The ISDN is carried in spare bits in the framing byte downstream (Figure 3), and in spare bits in the protocol bytes upstream ie. not in the data cells themselves.

At the network terminating equipment in the home, there are two outputs, namely, a link 6 which carries ATM into the home and could be connected to a TV set - top box, and could carry TV channels, even allowing for interactive viewing, and a link 7, which consists of4 or more copper wires which connects to standard ISDN services such as fax machines, computer connections and, or course, to a telephone. The telephone at least could be incorporated in the same overall housing as the network terminating equipment 3. Because there are four or more wires carrying the ISDN signal, this time in "S" format, the signals on the wires are simpler in nature than the "U" signals passing between the exchange and the multiplexer and the network terminating equipment 3. "S" format is described in ITU Reference I. 430 and "U" format is described in ETSI Reference ETS 300 012.

Referring to Figures 3 and 4, the downstream data from the multiplexer to the home is clocked at 25.6Mbit/sec, and the data is framed every 125µs. Thus there are 400 bytes per frame. This allows 7 fixed size data packets or cells to be accommodated, leaving 8 bytes for framing, which includes the synchronisation pattern.

Each cell contains an ATM (Asynchronous Transfer Mode) cell of 53 bytes, leaving 3 bytes per cell for forward error correction or cyclic redundancy check. These cells are in User Network Interface (UNI) format, described in ITU Recommendations I.150.

Referring to Figure 4, the upstream data from the home to the multiplexer has data clocked at 3.2Mbit/sec. This is also framed at 125µs, giving 50 bytes per frame.

The cells sent downstream have a number in a repeating pattern. This number is acknowledged. Thus, in operation, the multiplexer steadily sends frames of the type shown in Figure 3 to the network terminating equipment, and successive cells are given a sequence number in an increasing sequence modulo-8. To take an example, suppose that Cell 1 has the first sequence number Cell 2 the second etc. Cell 7 will have the 7th sequence number and Cell 1 of the next frame the 8th sequence number. Cell 2 of the next frame will have the sequence number given to Cell 1 of the first frame.

When Cell 1 of the first frame is received by the network terminating equipment, an acknowledgement is sent in the next protocol byte P1-P7 of the upstream frame. For example, P3 could be the next protocol byte to be sent, and 3 bits of each of the protocol bytes are set aside for the acknowledgements. Thus, those 3 bits would signal that the last successful cell sent was Cell 1.

The round trip is about 10µs, so that when this is received at the multiplexer 2, Cell 2 is in the process of being sent, each cell having a period of around 18µs. Accordingly Cell 3 is sent after Cell 2 even if it turns out that Cell 2 is not received. The sequence number of Cell 2 is read by the network terminating equipment and an acknowledgement that that sequence number has been received is sent in the first three bits of protocol byte 4.

The network terminating equipment expects each cell received to have an increasing sequence number on a modulo-8 basis. If, for example, due to noise, Cell 3 is not received at the network terminating equipment, protocol byte 5 will not send an acknowledgement, and the multiplexer will simply restart the sequence at Cell 3, even though it would by this time already have sent Cell 4, which may even have been validly received.

Other noteworthy features are that the framing cell contains analogue telephony (POTS - Plain Old Telephone System) or ISDN B channels and that four spare bits in the header [A] -Figure 3 are used to transmit ISDN D channel. The flow of ISDN in the other direction is contained in the protocol bytes of the upstream frame, as is analogue telephony. The ISDN thus does not suffer much from delay.

In the downstream direction (Figure 3) the ATM data is carried in the cells. In the upstream direction (Figure 4), 3 ATM cells of 56 bytes are spread over 4 upstream frames. The information as to where the next ATM cell starts is given in protocol byte 1.

A full acknowledgement with resends may be necessary under some noisy conditions. However, many errors may be of just one bit, so some error correction may be useful. An error correction of at least 2 bytes should be included in each cell, although 3 bytes would be preferable.

Given the cabling range the downstream data must use a send ahead protocol of at least one cell for range and a second cell to allow for delays through the VDSL processing. Upstream, a send ahead protocol would also be desirable, but could be perhaps avoided for a small loss of performance. (A send ahead protocol means that a certain number of cells, say, n are sent before receipt of the first is acknowledged. The second is acknowledged after n+1 cells have been sent etc. The data needs to be scrambled in a way which recovers quickly from errors. This could be the standard ATM scrambler of $1 + x^{43}$. The scrambling and the error detection/correction need to be considered together.

Under degraded line conditions, the downstream data rate could drop back to lower data rates. For example, the downstream rate could drop to three quarters of full rate ie. 19.2Mbit/sec, and there could be 5 cells to a frame or 21 cells to a multi-frame of 4 frames. If the data rate dropped to half ie. 12.8Mbit/sec and there were 200 bytes per frame, then there could be 3 cells in a frame, 7 in a multi-frame of 2 frames or 99 in a multi-frame of 28 frames. If the data rate dropped back to a quarter, corresponding to 100 bytes per frame, there could be 1 cell per frame, 3 per multi-frame of 2 frames, 5 per multi-frame of 3 frames or 141 per multi-frame of 84 frames.

As an example, the allocation of bits in the protocol bytes of the upstream frame could be as follows:

Protocol Byte	Bits	Meaning
P1	0-3	Acknowledgement for downstream cells
	4-7	Used to indicate frame of 4 to tell start of real ATM data. = 0 frame 1, cell starts immediately following = 1 frame 2, a cell starts in 14th data byte = 2 frame 3, a cell starts in 28th data byte = 3 frame 4, no cells start in frame
P2	0-3	Acknowledgement for downstream cells
	4-7	LSB of Pots channel 1
P3	0-3	Acknowledgement for downstream cells
	4-7	MSB of Pots channel 1
P4	0-3	Acknowledgment for downstream cells
	4-7	LSB of Pots channel 2
P5	0-3	Acknowledgement for downstream cells
	4-7	MSB of Pots channel 2
P6	0-3	Acknowledgement for downstream cells
	4-7	D channel ISDN
P7	0-3	Acknowledgement for downstream cells
	4-7	Spare

In Figure 4, S is the framing byte, which includes a synchronisation pattern.

As far as the upstream formats are concerned, an alternative of a higher data rate of 6.4Mbit/sec is possible. There would have to be more than one protocol in the downstream frame to control it. There would be 100 bytes to use, and there could be 7 acknowledgements for the downstream data spread over each frame. It should be possible to squeeze the POTS, these acknowledgements and some framing into say 8 bytes leaving 92 for data. Allowing for a cell format the same as for the downstream and same check field this fits exactly 23 cells in 14 frames. Or in simpler mappings,

3 cells in 2 frames or 8 in 5 frames.

The downstream protocol must handle a 1 (or 2) cell send ahead to keep the data rate up. A sophisticated selective retry mechanism would reduce the effect of errors but at a heavy protocol overhead, therefore a simple rewind back to a faulty cell method was chosen. With only a one cell ahead window, a small sequence number is required, 4 values being more than adequate, but provision must be made for the protocol to be reset to a fifth (empty value).

To achieve a 2 cell window, an 8 value sequence was chosen. A suitable set of sequence number values is as follows:

Sequence Number Value	Interpretation with data	Interpretation in acknowledgements
0000	No Cell	Sequence Reset
0001	Reset	Reset Request
0100	Cell with sequence 0	Last successful cell was seq #0
0101	Cell with sequence 1	Last successful cell was seq #1
0110	Cell with sequence 2	Last successful cell was seq #2
0111	Cell with sequence 3	Last successful cell was seq #3
1100	Cell with sequence 4	Last successful cell was seq #4
1101	Cell with sequence 5	Last successful cell was seq #5
1110	Cell with sequence 6	Last successful cell was seq #6
1111	Cell with sequence 7	Last successful cell was seq #7
Others (001x)	Reserved	Reserved

If the network terminating equipment gets reset, it sends a special "reset request" value as its last successful cell. If the multiplexer sees this value, it sends "reset" to the network terminating equipment. When the network terminating equipment gets this it responds "sequence reset", after which the multiplexer can send cell sequence #0 again. If the multiplexer suspects confusion it can send "reset" to the network terminating equipment itself. This ensures that the sequence works again after failure.

The above discussion has referred to the protocol for sending cells from the multiplexer to the network terminating equipment. The protocol for sending from the network terminating equipment to the multiplexer would be the same.

Referring to Figures 5 and 6, an alternative frame based on 24.576Mbit/sec upstream and 3.072Mbit/sec downstream is shown. This alternative frame is based on a standard telecoms data rate as 24.576 Mbit/sec is exactly 12 times 2.048 Mbit/sec commonly used in telecoms. Drop-back of the downstream rate to 18.432Mbit/sec or 12.280Mbit/sec would be possible and the upstream rate could be increased to 6.144Mbit/sec.

The framing can either be in the header as shown, or could be split with 1 byte in each place and 1 telephony channel in each place. Figure 5 shows telephony and ISDN in the second framing field. The multi-framing points forward to the start of the next cell, and is a common format for 12/18/24Mbit/sec downstream.

At 24.576Mbit/sec, the sequence will fit exactly 27 cells over 4 frames (22.876Mbit/sec of ATM. At 18.432Mbit/sec there are two options, either fully utilise with 141 cells over 28 frames (17.08Mbit/sec of ATM) or just have exactly 5 cells per frame and waste 2 bytes per frame. At 12.288Mbit/sec the sequence can be to fully utilise 93 cells over 28 frames (11.14Mbit/sec of ATM, or to do some form of partial fill).

The multi-frame needs to indicate 28 different values for the lower data rates. This cannot be achieved in a 4 bit field. There are two alternatives, one is to use part of another field, the other is to only indicate this information every other frame (14 values) and have a continuation indicator in the other frames. The proposal assumes that at 12/18Mbit/sec the alternate frame marking is used The proposal is to following:

Value	Distance to cell start (bytes) on a 24M Link	Distance to cell start on a 18M Link	Distance to cell start on a 12M Link
0	0	0	0
1	14	4	4
2	28	8	8
3	42	12	12

(continued)

Value	Distance to cell start (bytes) on a 24M Link	Distance to cell start on a 18M Link	Distance to cell start on a 12M Link
4	Not Used	16	16
5	Not Used	20	20
6	Not Used	24	24
7	Not Used	28	28
8	Not Used	32	32
9	Not Used	36	36
10	Not Used	40	40
11	Not Used	44	44
12	Not Used	48	48
13	Not Used	52	52
14	Not Used		
15	Not Used	Last +2	(Last + 20) Mod 56

For a 24Mbit/sec link this will cycle 0, 1, 2, 3, 0, 1, 2, 3	
For an 18Mbit/sec link this will cycle	0, 15, 1, 15, 2, 15, 3, 15, 4, 15, 5, 15, 6, 15, 7, 15, 8, 15, 9, 15, 10, 15, 11, 15, 12, 15, 13, 15, 0 ....
For a 12Mbit/sec link this will cycle	0, 15, 5, 15, 10, 15, 1, 15, 6, 15, 11, 15, 2, 15, 7, 15, 12,15,3, 15, 8, 15, 13, 15, 4, 15, 9, 15,0....

There are 48 or 96 bytes to use upstream, and there should be 7 acknowledgments for the downstream data spread over the frame. It should be possible to accommodate the POTS, these acknowledgements and some framing into say 8 bytes leaving 40 or 88 for data. The cells should fill the resultant pay-load which is a 7 frame sequence carrying 5 cells at 3.072Mbit/sec (2.42Mbit/sec of ATM, or at 6Mbit/sec) (not shown) it will carry 11 cells in a 7 frame sequence (5.56Mbit/sec of ATM).

In Figure 6, S refers to the synchronisation/framing byte, P1-7 indicate protocol bytes, elaborated below and ATM bytes carry ATM cell and check information.

The synchronisation byte gives a pattern that the multiplexer can latch onto to receive the data.

The protocol bytes are as shown below:

Protocol Byte	Bits	Value	Meaning
P1	0-3		Acknowledgement for downstream cells
	4-7		Used to indicate frame of 7 to tell start of real ATM data.
		=0	frame 1 at 3M, cell starts immediately following
		=1	frame 2 at 3M, a cell starts in 16th data byte
		=2	frame 3 at 3M, a cell starts in 32nd data byte
		=3	frame 4 at 3M, no cell starts in frame
		=4	frame 5 at 3M, a cell starts in 8th data byte
		=5	frame 6 at 3M, a cell starts in 24th data byte
		=6	frame 7 at 3M, no cell starts in frame
		=8	frame 1 at 6M, a cell starts immediately following (&56)
		=9	frame 2 at 6M, a cell starts in 24th data byte (&80)
		=10	frame 3 at 6M, a cell starts in 48th data byte
		=11	frame 4 at 6M, a cell starts in 16th data byte (&72)
		=12	frame 5 at 6M, a cell starts in 40th data byte

(continued)

Protocol Byte	Bits	Value	Meaning
		=13	frame 6 at 6M, a cell starts in 8th data byte (&64)
		=14	frame 7 at 6M, a cell starts in 32nd data byte
P2	0-3		Acknowledgement for downsteam cells
	4-7		LSB of Pots channel 1
P3	0-3		Acknowledgement for downstream cells
	4-7		MSB of Pots channel 1
P4	0-3		Acknowledgement for downstream cells
	4-7		LSB of Pots channel 2
P5	0-3		Acknowledgement for downstream cells
	4-7		MSB of Pots channel 2
P6	0-3		Acknowledgement for downstream cells
	4-7		Spare of D channel if wanted for ISDN
P7	0-3		Acknowledgement for downstream cells
	4-7		Spare

Claims

1. A method of delivering a higher data rate signal representing first services and a lower data rate signal representing second services along the same link, comprising the steps of receiving the separate signals from a communications network, and transmitting along the link the higher data rate signal in fixed size data packets within frames, the lower data rate signals being accommodated in time slots in the frames not occupied by the fixed size data packets.

2. A method as claimed in claim 1, in which the data packets transmitted across the link include a field containing a number which changes from packet to packet in a regularly repeating sequence, the receipt of the packet number in the sequence being acknowledged.

3. A method as claimed in claim 2, in which the number increments to n in a modulo-n sequence.

4. A method as claimed in claim 2 or claim 3, in which, in the event that the next packet in the sequence is not received across the link, the sequence being transmitted is restarted at that next packet.

5. A method as claimed in any one of claims 1 to 4, in which the higher data rate signal is ATM cells.

6. A method as claimed in any one of claims 1 to 5, in which the lower data rate signals are ISDN.

7. A method as claimed in any one of claims 1 to 6, in which the data is transmitted along the link at at least 6Mbit/sec.

8. A method as claimed in any one of claims 1 to 7, in which a higher data signal and a lower data rate signal, together with acknowledgements are transmitted in the opposite direction along the link in frames.

9. A multiplexer for delivering a higher data rate signal representing first services and a lower data rate signal representing second services along the same link, comprising ports for reception from a communication network of the separate signals, and means for transmitting along the link the higher data rate signal in fixed size data packets within frames, the lower data rate signal being accommodated in time slots in the frames not occupied by the fixed size data packets.

10. A multiplexer as claimed in claim 9, in which the transmitting means is such that the data packets transmitted across the link include a field containing a number which changes from packet to packet in a regularly repeating

sequence, the receipt of the packet number in the sequence being acknowledged.

11. A multiplexer as claimed in claim 10, in which the number increments to n in a modulo-n sequence.

12. A multiplexer as claimed in claim 10 or claim 11, in which the higher data rate signal is ATM cells.

13. A multiplexer as claimed in any one of claims 9 to 12, in which the lower data rate signals are ISDN.

14. Network terminating equipment for receiving a higher data rate signal representing first services and a lower data rate signal representing second services along the same link from a multiplexer, comprising means for receiving from the link the higher data rate signals in fixed size data packets within frames, the lower data rate signal being accommodated in time slots in the frames not occupied by the fixed size data packets, and means for extracting the first services and the second services.

15. Network terminating equipment as claimed in claim 14, which is arranged, in responses to receipt of data packets which include a field containing a number which changes from packet to packet in a regularly repeating sequence, to acknowledge the receipt of the packet number in the sequence.

16. Network terminating equipment as claimed in claim 15, in which the higher data rate signal is ATM cells.

17. Network terminating equipment as claimed in claim 15 or claim 16, in which the lower data rate signals are ISDN.

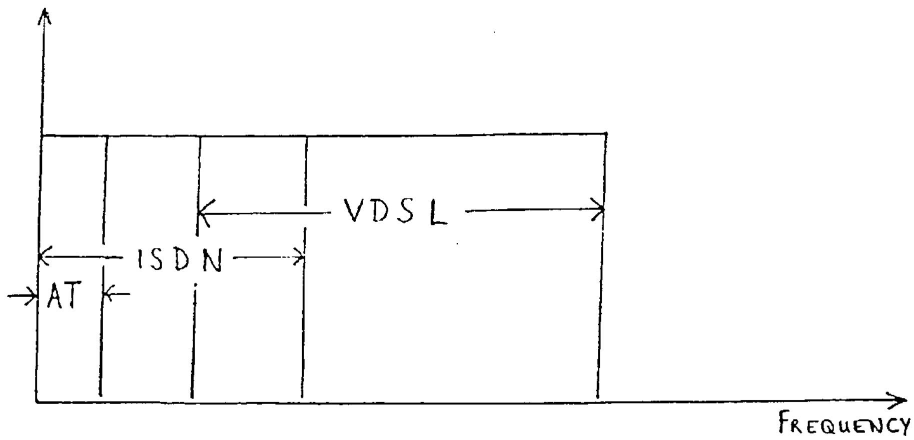
VDSL
ISDN
AT
FREQUENCY

FIG 1

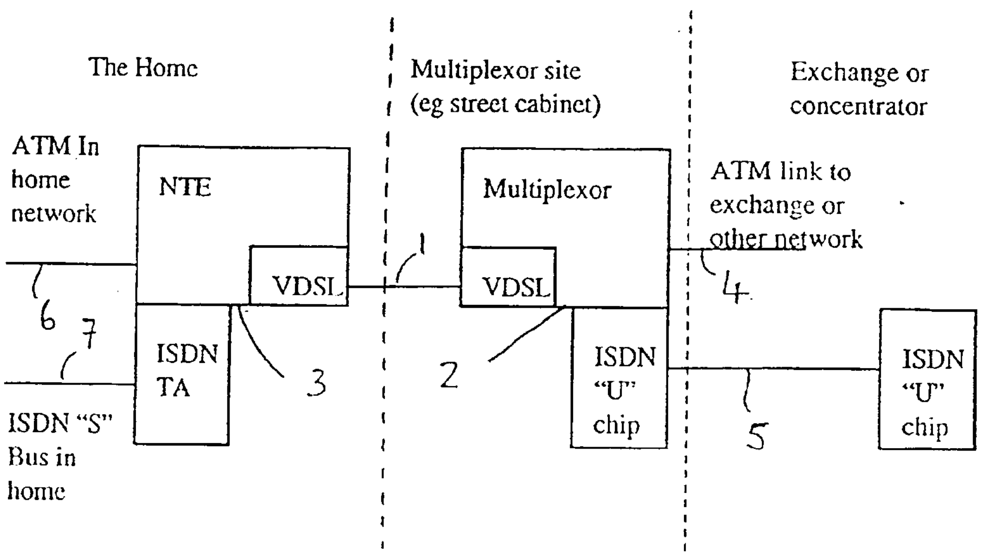
The Home
Multiplexor site
(eg street cabinet)
Exchange or
concentrator
ATM In
home
network
NTE
VDSL
Multiplexor
VDSL
ATM link to
exchange or
other network
1
4
6
7
ISDN
TA
3
2
ISDN
"U"
chip
5
ISDN
"U"
chip
ISDN "S"
Bus in
home

FIG 2

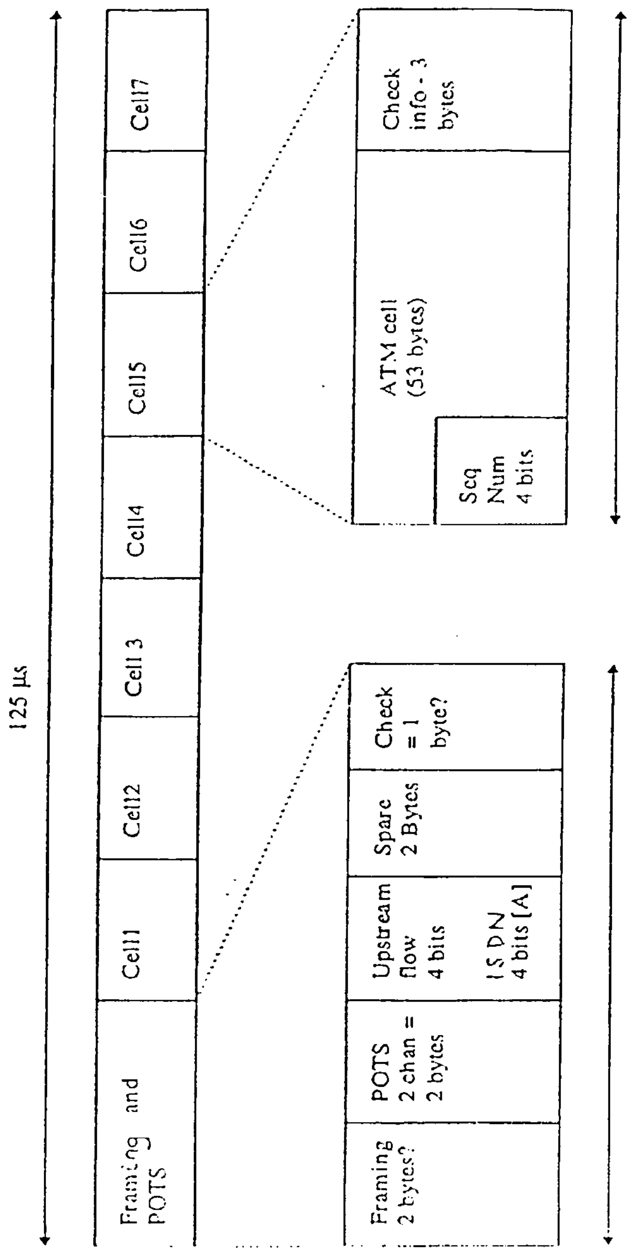
125 µs
Framing and POTS
Cell1
Cell2
Cell 3
Cell4
Cell5
Cell6
Cell7
Framing 2 bytes?
POTS 2 chan = 2 bytes
Upstream flow 4 bits
ISDN 4 bits [A]
Spare 2 Bytes
Check = 1 byte?
8 bytes
Seq Num 4 bits
ATM cell (53 bytes)
Check info - 3 bytes
56 bytes

FIG 3

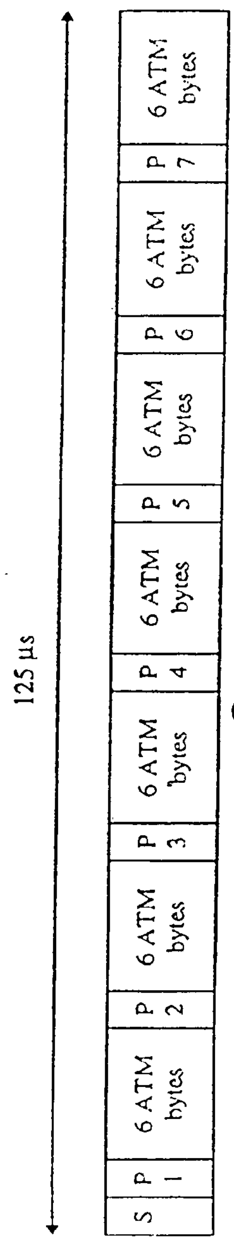
125 µs
S
P 1
6 ATM bytes
P 2
6 ATM bytes
P 3
6 ATM bytes
P 4
6 ATM bytes
P 5
6 ATM bytes
P 6
6 ATM bytes
P 7
6 ATM bytes

FIG 4

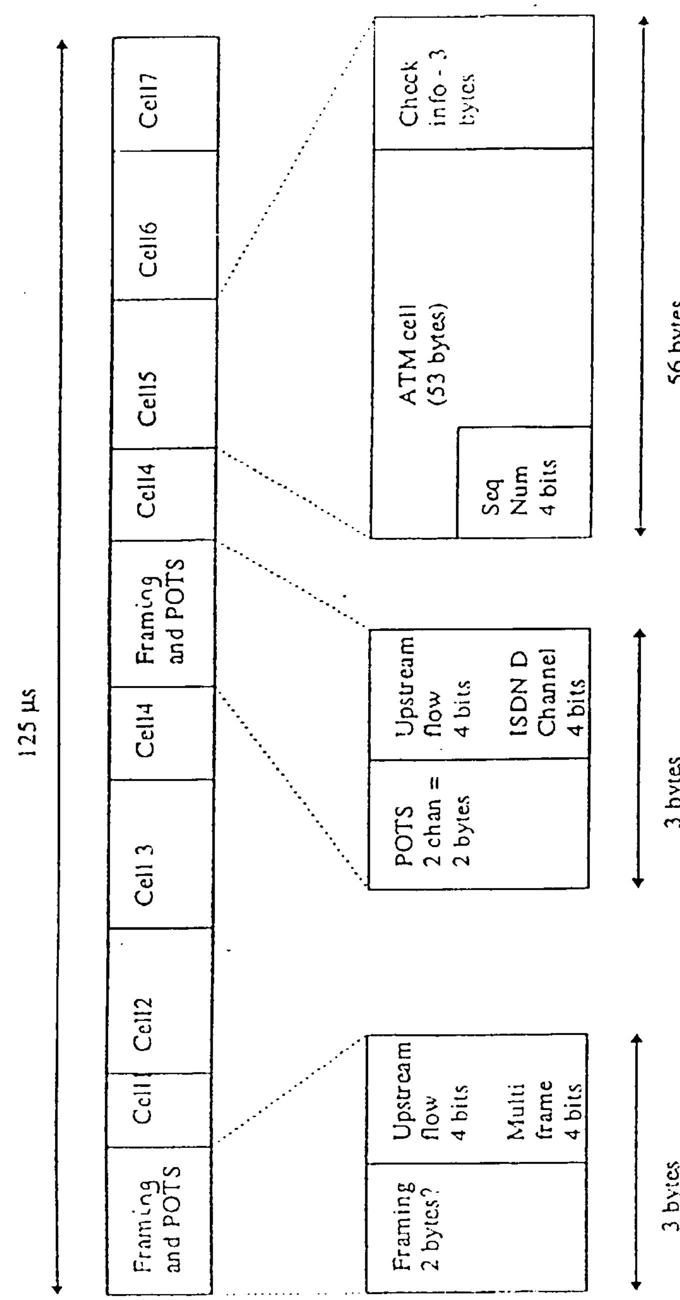
125 µs
Framing and POTS
Cell1
Cell2
Cell 3
Cell4
Framing and POTS
Cell4
Cell5
Cell6
Cell7
Framing 2 bytes?
Upstream flow 4 bits
Multi frame 4 bits
POTS 2 chan = 2 bytes
Upstream flow 4 bits
ISDN D Channel 4 bits
Seq Num 4 bits
ATM cell (53 bytes)
Check info - 3 bytes
3 bytes
3 bytes
56 bytes

FIG 5

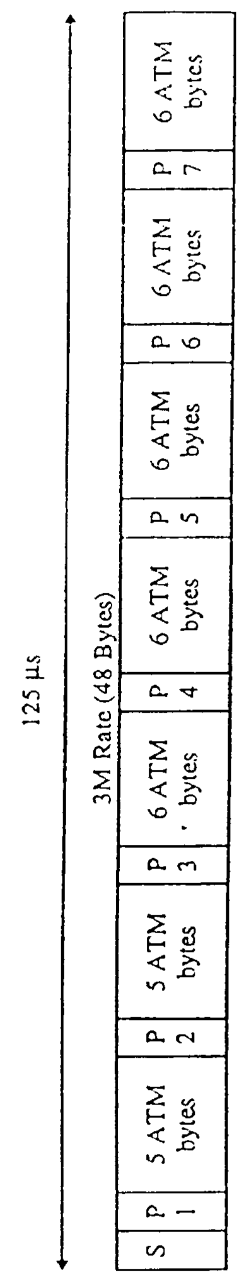
125 µs
3M Rate (48 Bytes)
S
P 1
5 ATM bytes
P 2
5 ATM bytes
P 3
6 ATM bytes
P 4
6 ATM bytes
P 5
6 ATM bytes
P 6
6 ATM bytes
P 7
6 ATM bytes

FIG 6